# VISUAL REINFORCEMENT IN THE FEMALE SIAMESE FIGHTING FISH, BETTA SPLENDENS

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Operant conditioning with *Betta splendens* (*Bettas*) has been investigated extensively using males of the species. Ethological studies of female *Bettas* have revealed aggressive interactions that qualitatively parallel those between male *Bettas*. Given these similarities, four experiments were conducted with female *Bettas* to examine the generality of a widely reported finding with males: mirror-image reinforcement. Swimming through a ring was reinforced by a 10–s mirror presentation. As with males, ring swimming was acquired and maintained when mirror presentations were immediate (Experiments 1, 2, and 3) and delayed (Experiment 4). The failure of conventional extinction (Experiments 1 and 2) and response-independent mirror presentations (Experiment 3) to maintain responding confirmed the reinforcing properties of mirror presentation. These results extend previous findings of mirror images as reinforcers in males of the same species and illustrate a complementarity between behavioral ecology and the experimental analysis of behavior.

*Key words:* mirror-image reinforcement, extinction, response-independent mirror presentation, aggression, ring swimming, female *Betta splendens*

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The aggressive display of male Siamese fighting fish, *Betta splendens* (hereafter, *Bettas*), is reliably elicited by images of another male *Betta*. Visual reinforcement of the responding of these males also has been demonstrated repeatedly when such images are presented dependent on a specified response. In different experiments, visual access to models of other male *Bettas* (Thompson & Sturm, 1965), a live male or female conspecific (Rnic, 1977), mirror presentations resulting in an image of the fish serving as the experimental subject (Lattal & Metzger, 1994; Thompson, 1963), and film clips of another *Betta* (Turnbough & Lloyd, 1973) all are sufficient to develop and maintain operant responding in male *Bettas*. In addition, the color of the fish presented as a model (Thompson & Sturm), duration of mirror presentation (Wirth, Lattal, & Hopko, 2003), delay of mirror presentation from the response (Lattal & Metzger), and schedule of reinforcement (Turnbough & Lloyd) each influence the probability of the operant response. Such responding for visual rein-forcement also has been reported for other members of the *Anabantoid* family to which the *Betta* belongs. In male paradise fish (*Macropodus opercularis*), for example, mirror images elicit aggressive displays (Francis, 1983) and strengthen and maintain operant responses (Melvin & Anson, 1970).

Female *Bettas* also display aggressively toward one another in a manner similar to that of males (Braddock & Braddock, 1955; Robertson, 1979). Braddock and Braddock, for example, described the female aggressive display as follows:

> Individual challenging is a stereotyped reaction. The aggressor approaches the other fish, usually at an angle, and stops at a distance of less than 1 inch. It then erects its gill covers, holds its body rigidly in a flexed position, erects all its median fins, and rapidly vibrates the pectoral fins. The color of the body and fins becomes more intense, and striping tends to disappear. Individual challenges may be almost instantaneous or prolonged for 30 seconds or more. (p. 155)

Even though Braddock and Braddock (1955) observe that females can behave aggressively with one another, females typically are housed communally without the intensity of aggressive interactions that preclude such housing of males. On the one hand, this lack of propensity for aggression that allows communal living suggests that visual access to a mirror image might not function with females as it does with males. On the other hand, there

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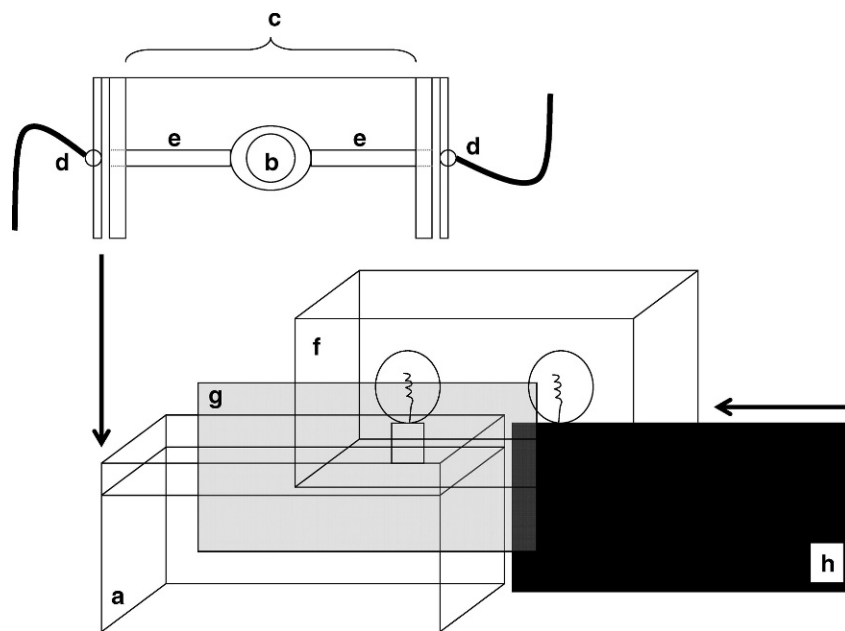
Fig. 1. Diagram of the apparatus: (a) Aquarium where the fish were housed; (b) Ring through which each fish swims; (c) Plexiglas frame that holds the photobeam placed outside the narrow sides of the aquarium; (d) One part of the photobeam; (e) Plexiglas rods; (f) Box with the two light bulbs; (g) One-way mirror; and (h) Black panel to cover the mirror before and after the session.

are qualitative similarities of the display of female and male *Bettas* toward conspecifics. This latter observation combined with the susceptibility of males to visual reinforcement as noted suggests that access to a mirror image by a female *Betta* might function as a reinforcer as it does in males. The present experiments therefore examined mirror presentation as a reinforcer of operant responding by female *Bettas*.

## METHOD

### Subjects

Fifteen experimentally naïve female *Bettas* were obtained from local pet stores. Each was housed individually in the aquariums described below. Each aquarium was arranged to ensure visual isolation of each *Betta*. Water was maintained between 21 and 24°C and was replaced regularly after first being chemically treated to eliminate chlorine. Food was provided daily, 20–30 min after the experimental session.

### Apparatus

Each of four aquariums was housed in a small room that was acoustically and visually isolated from the control equipment. Ambient light in the room was programmed on a 12 hr light/dark cycle. During each session, the ambient light was on. Temperature and humidity in the room were held constant. An example of the apparatus is diagrammed in Figure 1 (all letter references in this description are to this figure). Each aquarium was 20.5 cm high by 30 cm long by 14.5 cm wide and contained approximately 9.5 L of water (*a*). The device used to record responses was a plastic ring (*b*), with a 4.5 cm inner diameter, and supported by a Plexiglas frame (cf. Wirth et al., 2003) that fit over the two narrow sides of the aquarium (*c*). Part of the frame remained outside the aquarium and contained a light source and photoreceptor (*d*). The part of the frame that was placed inside the aquarium consisted of two 1.4-cm-diameter clear plastic rods (*e*) that terminated near the center of the aquarium at the outer edge of the plastic ring. The Plexiglas rods allowed transmission of infrared light from one side of the aquarium to the other without being refracted by the water. The ring was placed in the aquarium such that its opening was parallel to the long sides. When the fish swam

Table 1

Number of Sessions and Mean (SD) Response Rate for Each Fish in Each Experiment.

| Fish | Number of Sessions | | | Mean (SD) Response Rate | | |
|---|---|---|---|---|---|---|
| | FR 1 | EXT | FR 1 | FR 1 | EXT | FR 1 |
| Experiment 1 | | | | | | |
| F1 | 29 | 3 | | 12.6 (0.08) | 3.6 (0.02) | |
| F2 | 29 | 3 | | 17.4 (0.16) | 6.0 (0.03) | |
| F3 | 29 | 3 | | 40.2 (0.19) | 6.0 (0.03) | |
| F4 | 27 | 3 | | 15.6 (0.08) | 6.0 (0.01) | |
| Experiment 2 | | | | | | |
| 2A | 34 | 13 | 16 | 16.8 (0.14) | 2.4 (0.03) | 9.6 (0.07) |
| 4A | 34 | 13 | 21 | 8.4 (0.06) | 4.2 (0.05) | 30.6 (0.25) |
| F1 | 12 | 8 | 11 | 9.6 (0.03) | 2.4 (0.02) | 12.0 (0.04) |
| F2 | 12 | 8 | 12 | 9.0 (0.05) | 2.4 (0.03) | 13.2 (0.09) |
| Experiment 3 | | | | | | |
| F11 | 20 | 10 | 12 | 12.6 (0.08) | 1.2 (0.02) | 8.4 (0.04) |
| F12 | 26 | 10 | 17 | 22.2 (0.05) | 0.0 (0.00) | 13.2 (0.05) |
| F13 | 40 | 10 | 27 | 39.0 (0.04) | 1.8 (0.04) | 36.0 (0.13) |
| | Tandem FR 1 DRO 10 s | | | Tandem FR 1 DRO 10 s | | |
| Experiment 4 | | | | | | |
| M1 | 16 | | | 13.2 (0.10) | | |
| M2 | 16 | | | 23.4 (0.14) | | |
| M3 | 10 | | | 0.0 (0.00) | | |
| M4 | 16 | | | 3.0 (0.59) | | |

*Note*: Mean and SD of the response rates were calculated for the last six sessions of each condition, except for the extinction condition of Experiment 1 for which the mean and SD are based on the three extinction sessions.

through the ring, breaking the photobeam, a response was recorded.

A 25.5 cm high by 35.5 cm long by 13.5 cm wide box housed two 40-W 110-V light bulbs behind a clear plastic front panel (*f*). This panel was located in front of one of the long sides of the aquarium. A one-way mirror (25.5 cm by 35.5 cm) was placed between the clear panel and the aquarium (*g*). When the light bulbs were on, no image of the fish was displayed, and when the light bulbs were turned off, the reflection of the fish was displayed on the mirror thus created. The other three sides of the aquariums were covered with black panels to ensure visual isolation. At the end of each session, the mirror also was covered by a black panel (*h*). The photocells were interfaced to a personal computer, located in an adjacent room, through a MedAssociates® interface. Programming and data collection were arranged using MedPC® software.

*Procedure*

All sessions were conducted in the home aquariums during the light-on cycle, 6–7 days per week at approximately the same time. Thus, the subjects were never removed from their aquariums. Each session lasted 120 min in the first three experiments and 90 min in Experiment 4. The sequence of conditions and number of sessions per condition for each experiment is shown in Table 1. Conditions were changed when there were no systematic trends in response rates as judged by visual inspection in Experiments 1–3, except as noted below. In Experiment 4, the number of sessions was fixed for each subject. Because there were only four aquariums, 4 fish were studied at a given time.

The following procedures were common to all four experiments: There was no explicit training of the response. Immediately before each session, the frame was emplaced and the lights were illuminated behind the one-way mirror. The mirror then was uncovered and the session began. During each session, reinforcement consisted of a 10-s period during which the lights behind the mirror were extinguished, making the mirror reflective. A 10-s period of mirror access was selected based on Wirth et al.'s (2003) findings that durations between 3 and 15 s were effective in maintaining responding of male Bettas (cf. Turnbough

& Lloyd, 1973). The unique features of each experiment were as follows.

*Experiment 1.* Acquisition and maintenance of ring swimming were studied by exposing 4 fish to a fixed-ratio (FR) 1 schedule of reinforcement. When the fish swam through the ring, the lights behind the mirror were extinguished for 10 s, thereby making the mirror reflective. After 10 s, the lights again were illuminated, removing the mirror's reflection. This sequence repeated following each such response.

After 27–29 sessions of exposure to the FR 1 schedule, extinction (EXT), defined as the removal of the mirror presentation following a response (i.e., the lights behind the mirror were on continuously), was in effect for three consecutive sessions.

*Experiment 2.* To examine further how responding is maintained by the mirror presentation, the procedures of Experiment 1 were replicated and extended, with a reversal following extinction. Four experimentally naïve fish were exposed to the FR 1 schedule described in Experiment 1. Of these 4 fish, Fish 2A and 4A acquired ring swimming. Therefore, Fish F1 and F2, previously used in Experiment 1, were retrained on the FR 1 schedule and used in this experiment. After 12–34 sessions of exposure to this FR 1 schedule, EXT, as described in the first experiment, was in effect for 8–13 sessions. Finally, the FR 1 schedule was reinstated for 11–21 sessions. During the first FR 1 condition, for Fish 2A EXT was introduced even though responding did not appear stable because the responding was on an upward trajectory and the subsequent extinction condition was expected to decrease responding. During the last FR 1 condition for Fish 4A, the experiment was terminated after 21 sessions.

*Experiment 3.* To examine the role of the dependency between the ring-swimming response and mirror presentation on response maintenance, responding was compared when reinforcers were delivered under an FR 1 schedule of mirror presentation to those delivered according to a yoked variable-time (VT) schedule. Three experimentally naïve fish were exposed to an FR 1 schedule of mirror presentation as described in Experiment 1. After 20–40 sessions on the FR 1 schedule, a VT schedule was in effect for 10 sessions. During the VT schedule, mirror presentations occurred independently of the responses of the fish. The values of each VT schedule were yoked to the mean interreinforcer intervals (IRI) of the last 6 sessions of the preceding FR 1 condition to equate the number of reinforcers in the two conditions. This mean value was calculated for each fish separately. Values for the VT schedule were generated according to a Fleshler and Hoffman (1962) progression. After 10 such yoked VT sessions for each fish, the FR 1 schedule was reinstated for 12–27 sessions.

*Experiment 4.* In the first three experiments, during the FR 1 schedules, a mirror presentation always immediately followed the ring-swimming response. Lattal and Metzger (1994) showed that responding of male *Bettas* was acquired even if the mirror presentation did not immediately follow the response. This experiment examined delayed reinforcement with females. Four experimentally naïve females were exposed to a tandem FR 1 differential-reinforcement-of-other-behavior (DRO) 10-s schedule. Thus, once the session started, when the fish swam through the ring, an unsignaled resetting 10-s delay was initiated (cf. Lattal & Metzger, 1994). During this delay, each response restarted the 10-s interval. Following a 10-s period without a response, the mirror was presented for 10 s and then removed as described in Experiment 1. This sequence repeated following each response. This procedure was in effect for 16 sessions.

## RESULTS

Response rates were calculated by dividing the number of ring swims by the session time, minus the mirror presentation time.

*Experiment 1.* Figure 2 shows responses per hr during each session for each fish. Fish F1, F2, and F3 responded for the first time during the third session. Fish F4 first responded during the eighth session. Of the average response rates over the last six sessions, Fish F3 showed the highest (40.2 responses per hr) and Fish F1 the lowest (12.6 responses per hr). For each fish, response rates decreased substantially during EXT. Fish F4 ceased responding.

*Experiment 2.* Figure 3 shows responses per hr for each fish. Fish 2A first responded during the third session and Fish 4A during the sixth session. Responding occurred earlier in Fish 1
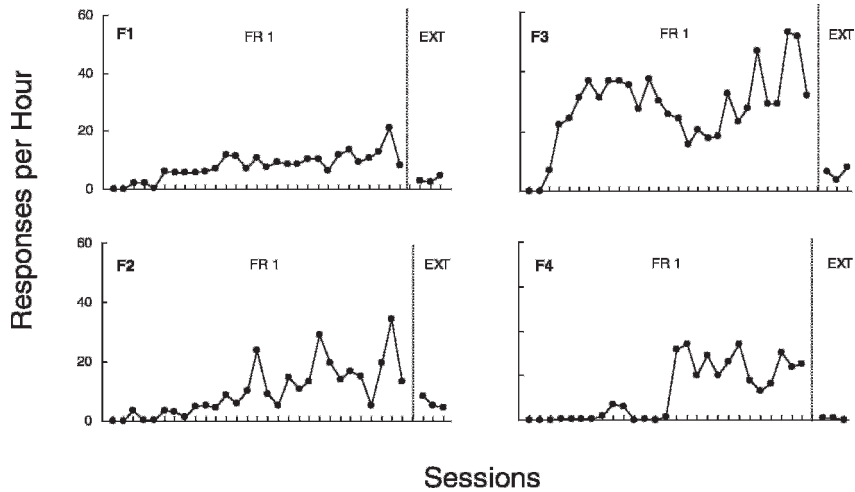
Fig. 2.   Responses per hr across sessions for each fish in Experiment 1. Conditions (FR 1 & EXT) are separated by a dashed vertical line.

and 2, presumably because of their previous exposure to the FR 1 schedule. Across fish, average response rates for the last six sessions during both FR 1 conditions ranged from 8.4–30.6 responses per hr. For Fish 2A, F1, and F2, responding decreased substantially during EXT. For these same fish, responding recovered when the FR 1 schedule was reinstated. Fish 4A responded at lower rates during the FR 1 schedule than did the other fish. During EXT, response rates for Fish 4A decreased slightly, and primarily toward the end of the

EXT condition, relative to those during the preceding FR 1 schedule. After several subsequent sessions of the return to the FR 1 schedule, however, response rates were considerably higher for each fish than during the preceding EXT condition.

*Experiment 3.*   Figure 4 shows that, for each fish, response rates were substantially lower during the VT schedule relative to those during the FR 1 schedule. Response rates of each fish recovered when the FR 1 was reinstated. The average response rate for the
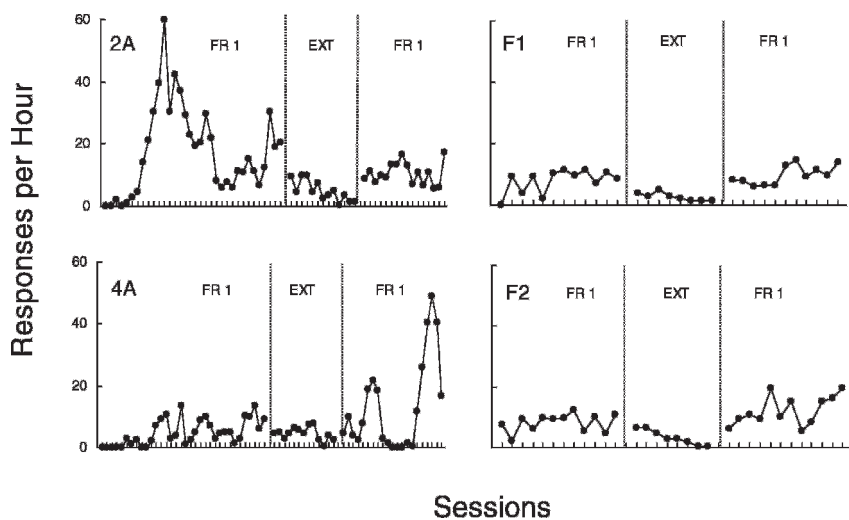


Fig. 3.   Responses per hr across sessions for each fish in Experiment 2. Conditions (FR 1, EXT, & FR 1) are separated by dashed vertical lines.
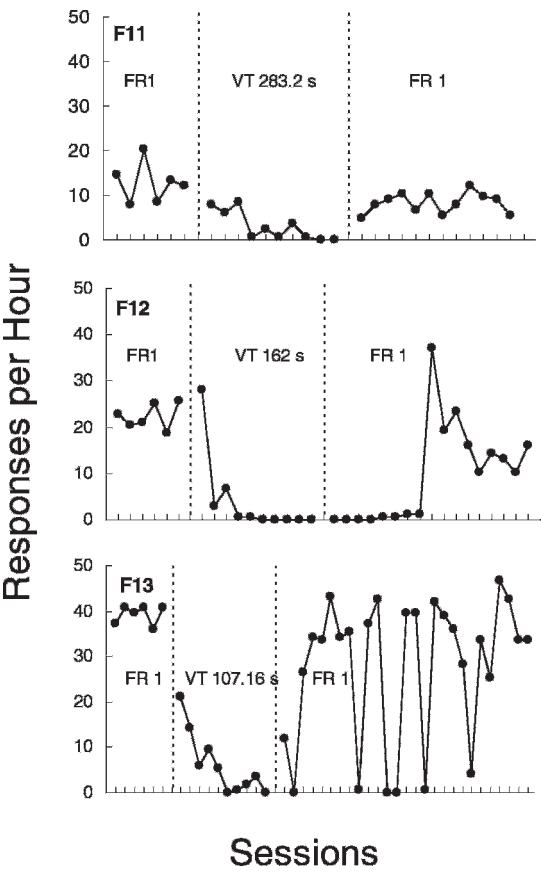
Fig. 4. Responses per hr over the final six sessions of the initial FR 1 condition and across all sessions of the yoked VT and the final FR 1 conditions for each fish in Experiment 3. Conditions (FR 1, VT, & FR 1) are separated by dashed vertical lines.

last six sessions during both FR 1 conditions (see Table 1) was highest for Fish F13 (39.0 and 36.0 responses per hr) and lowest for Fish F11 (12.6 and 8.4 responses per hr).

*Experiment 4.* Of the 4 fish, 3 acquired ring swimming even though reinforcement always was delayed by 10 s from a response. Figure 5 shows that response rates of Fish M1 and M2 increased systematically across sessions, but Fish M4 responded more erratically and at much lower rates during the experiment.

As with most other studies of the reinforcing efficacy of mirror presentations for *Bettas*, systematic observations of the visual displays during mirror presentations were not made during these experiments. The female *Bettas*, however, were informally observed from time to time during mirror presentations. These

observations revealed displays that were consistent with those observed by Braddock and Braddock (1955) when females were placed together and allowed to interact.

## DISCUSSION

Braddock and Braddock (1955) concluded that ''the female pattern [of aggression] … resembles closely that of the male [*Bettas*]'' (p. 170). The results of the four present experiments taken together show that response-dependent mirror presentation maintains responding in female *Bettas* in a similar manner to that of males of the same species under similar conditions (cf. Lattal & Metzger, 1994; Wirth et al., 2003). The congruence between the aggressive behavior of male
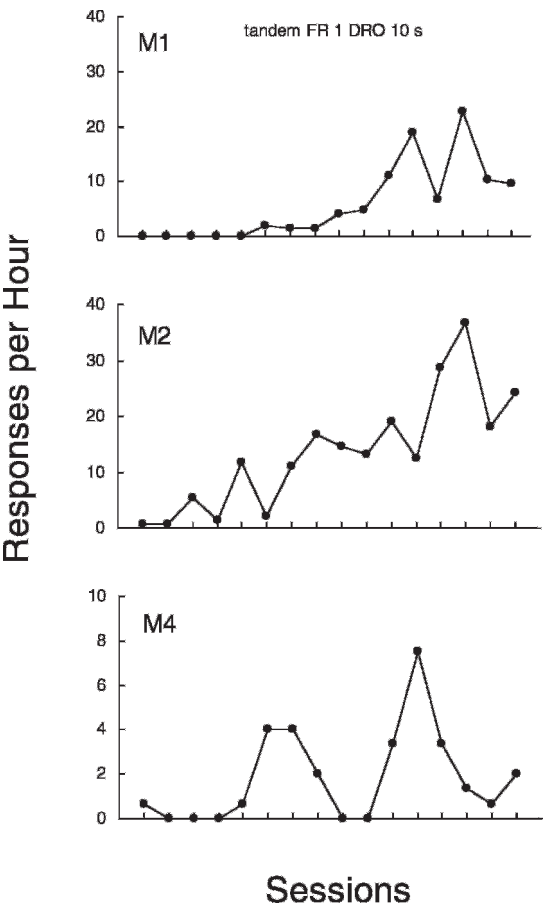


Fig. 5. Responses per hr across sessions for the 3 fish in Experiment 4 that acquired responding. Note the differences in the scale of the y axis for Fish M4.

*Bettas* exposed directly to one another and the reinforcing properties of mirror presentation with these fish is well established. The present results in concert with the naturalistic observations of Braddock and Braddock show a similar congruence between aggressive behavior and visual reinforcement for females.

Several features of the present findings can be compared to the results obtained with male *Bettas* in previous experiments. Both Lattal and Metzger (1994) and Wirth et al. (2003) used the same apparatus employed in the present study, but with male *Bettas*. Across the four present experiments, the acquisition of ring swimming with immediate or delayed (for 10 s) reinforcement was obtained in 12 out 15 female fish. These numbers are similar to results reported in the two aforementioned experiments. There were no obvious differences in appearance or behavior outside the experimental sessions between the 12 fish that acquired ring swimming and the 3 that did not (2 in Experiment 2 and 1 in Experiment 4). Some of the variability in acquisition may relate to the absence of shaping of the response. Although response shaping is the *sine qua non* of developing new responses in operant conditioning procedures, several experiments have shown that shaping is unnecessary in the development of sustained operant responding. Lattal and Gleeson (1990), for example, showed that responding of both rats and pigeons was acquired without any response training even though the operant response produced a reinforcer only after an unsignaled delay period that commenced with the response (Lattal & Williams, 1991; Wilkenfield, Nickel, Blakely, & Poling, 1992). Shaping also was unnecessary for response acquisition with either male or, in these experiments, female *Bettas*.

Under the present FR 1 schedules of immediate reinforcement with females (Experiments 1, 2, and 3), response rates varied between 0 and 40.2 responses per hr. Response rates under FR 1 schedules also were variable across individual male *Bettas* in both Lattal and Metzger (1994) and Wirth et al. (2003), ranging between near-zero and almost 400 responses per hr, depending on the conditions in effect (Wirth et al. manipulated reinforcer duration). With the unsignaled resetting 10-s delays in Lattal and Metzger,

response rates of 4 males varied between about 30 and 50 responses per hr toward the end of that condition. In the present Experiment 4, the response rates of the females ranged between 3.0 and 23.4 responses per hr toward the end (last six sessions) of the experiment. Two variables that may have contributed to the low response rates in all of these studies were the absence of shaping of the response, discussed above, and the nature of the operant response of swimming through a ring. This latter response involves movement of the entire body through a liquid medium that offers considerable resistance, as opposed to the bar press studied in rats or the key peck characteristic of pigeon operant conditioning experiments. In addition, there may be incompatible responses occurring concurrently with the operant response, such as persisting at mirror approach following termination of the mirror presentation.

Braddock and Braddock's (1955) seminal laboratory-based research in an ethological tradition was the first to document both topographical characteristics and controlling variables of aggressive behavior of female *Bettas*. The previously noted congruence between the Braddock and Braddock observations and the reinforcing efficacy of a mirror presentation for both males and females invites questions about the ecological significance of such a reinforcer, in terms of its origins and possible role in survival. Skinner (1966) described how susceptibility to certain kinds of reinforcers might come about through phylogenic contingencies. One function of aggressive behavior by females was suggested by Braddock and Braddock to be that of maintaining territory. If this is the case in natural settings, female *Bettas* could be thought of as actively seeking out potential intruders in the same way that a hungry rat forages for food. If this is the case, then the sequence of events can be likened to those proposed by Abarca and Fantino (1982), Collier (1980), Lea (1979), and others. First, searching occurs in the form of the operant response (e.g., Fantino, 1991) followed by procuring, in the form of approaching the mirror, and then handling, in the form of the aggressive display, which Braddock and Braddock have shown to be a necessary first step in an actual attack, which would, in this model, constitute the final consumption.

At this point, there are insufficient ethological data to either substantiate or refute the territorial function of aggression in female *Bettas*. Regardless of its survival significance, the aggressive behavior of female *Bettas*, including the susceptibility to reinforcement of operant responses leading to mirror-image presentations, has been shown in the present experiments to be a reliable finding in many members of the species. With respect to survival significance, Braddock and Braddock (1955) suggest that ''the student of animal behavior … is still interested in what various species are capable of doing. It is the range of capability that is of primary importance rather than what does or does not happen in nature'' (Braddock & Braddock, 1955, p. 171). The present results not only suggest dimensions of operant responding in female *Bettas*, but also complement findings with other species (e.g., fighting cocks, Thompson, 1964; other anabantoid fishes, Melvin & Anson, 1970; and pigeons, Pitts & Malagodi, 1996) to show the generality of mirror-image reinforcement.

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